the westbury community development centre
IT 4455/00

Interim Report of a DRM Mode E Trial in South Africa

V1.4

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Project Partners:

Kofifi Media Group, Roodepoort, South Africa

BluLemon, Edenvale, South Africa

CR Electronics, Springs, South Africa

Genssoft Technologies, Midrand, South Africa

British Broadcasting Corporation, London, UK

Fraunhofer IIS, Erlangen, Germany

Document History

Version Number	Date	Item changed/added
0.1	05 June 2017	Template prepared from license application, research, strategy and regulatory documentation
0.2	09 June 2017	Changed/added: Structure, objectives, timelines, systems, methodology
0.3	12 June 2017	Changed: Structure; Added: Results
0.4	13 June 2017	Added: Contributors, Copyright
0.5	22 June 2017	Added: Drive-by measurements, propagation Maps, and explanations
1.0	30 June 2017	Touch-ups
1.4	07 July 2017	About WECODEC and Project Partners, final touch-ups and release

Contents

1. Executive Summary

The Westbury Community Development Centre Trust (WECODEC), license holder of Kofifi FM 97.2, a community radio station in Westbury, South-West Johannesburg, with support from the British Broadcasting Service (BBC) and Fraunhofer Institute for Integrated Circuits, initiated a trial broadcast project to evaluate the Digital Radio Mondiale (DRM) system in the VHF Bands (also referred to as DRM Mode E or DRM+).

A 2-fold trial frequency spectrum license has been issued by ICASA for Johannesburg on 101.25MHz and Carnavon on 64.0MHz and became effective on 03 March 2017 for a period of 8 months. The license may be extended for a maximum of another 6 months if the need arises. Transmissions have started in Johannesburg from end of March 2017. Transmissions in Carnavon will start at a later stage as site preparations are not finalized yet.

So far mobile measurements have taken place in 4 radial directions as well as a round trip and various additional mobile measurement excursions with both professional and (pre-) consumer receiver equipment. The main technical objectives of the trial – acquiring evidence of no interference with adjacent FM channels and evaluation of the propagation characteristics of the signal – have so far successfully been achieved. This interim report that has been requested by ICASA contains all propagation maps and measurement results so far. However, a more detailed report at the end of the trial period will document the findings in further particulars.

Apart from the technical evaluation, our trial is also intended to evaluate the benefits for the broadcasters, listeners and economic environment.

For the Johannesburg transmission we are using a Nautel 2.5kW transmitter operating at 175W resulting in an estimated ERP of 500W on our stacked 4 vertical dipole antenna located at Rahima Moosa Hospital in Coronationville with an approximate antenna height of 70m above ground level. Although mobile reception is still impacted by prematurity of receivers without an appropriate AGC mechanism, audio decoding was possible at almost all predicted areas and beyond and showed a similar or better behaviour than FM audio reception of the analogue signal that is transmitted from the same site depending on the terrain.

Power consumption per channel is significantly lower than FM.

Both adjacent channels – RSG Pretoria on 101.0MHz and RSG Johannesburg (Brixton) on 101.5MHz were not interfered by our transmissions whilst an analogue allocation of the same frequency (101.25MHz) is not possible. Hence it was demonstrated that the existing FM spectrum could accommodate a large number of additional DRM radio channels without impacting existing services.

The other way around it was also demonstrated that the adjacent channel RSG on 101.5MHz transmitting at 33kW ERP (18dB stronger) did not impact the reception of our signal even at a difficult indoor scenario.

Along 3 audio services using the latest xHE-AAC audio codec, various text and data services including Journaline are broadcasted and were successfully decoded with both professional and consumer receivers. These will be evaluated further during the course of the trial.

This interim report can already be used for evaluation of the DRM system in the VHF Band (DRM+).

2. Introduction

DRM (Digital Radio Mondiale) is a digital radio standard, initiated by the DRM consortium in 1998 and later adopted by ITU. The consortium developed this digital transmission system for the AM-band, i.e. for long-, medium- and short waves (up to 30 MHz, DRM Mode A-D) and launched this system worldwide. The extension of the DRM system family to upper frequency bands from 30MHz up to 254 MHz, called DRM+ (DRM Mode E) is standardized under ETSI ES 201980 V3.1.1 (2009-02-16) and ITU-R Rec. BS.1660. DRM is a spectrum efficient system with a bit rate capacity in Mode E up to 186 kbps at only 96 kHz bandwidth. The COFDM modulation techniques combined with the appropriate use of a guard interval enables single frequency network (SFN) operation, and robust mobile reception up to 300 km/h also in multipath environments.

The data services, multiplexing and signalling schemes are the same as in the earlier established part of the DRM standard. In Mode E, a wide range of possible data rates from 37 to 186 kbit/s allows for a flexible use of the multiplex with respect to the number and type of programs (audio, data, video) adjusted to the broadcasters' requirements and preferences. Up to four radio services with excellent sound quality (MPEG4 xHE-AAC) including 5.1 surround sound (HE-AAC V2) can be transmitted within a single the DRM+ signal. In addition to the audio services several kinds of service information like MOT, TPEG, EPG, Journaline, text messages etc. can be transmitted. Many of the multimedia services are also standardised in DAB/DAB+ so DRM can be perfectly combined with the existing AM/FM/DAB+ transmission networks and ensures switching (also seamless) between different programs at the receiver side. The DRM System is an open standard and due to its small bandwidth it fits very well into the European/African AM and FM raster.

3. Co-existence of DRM+ and FM in VHF Band II: Johannesburg Example

One of the main objectives of the development of DRM+ was the possibility of a close placement of DRM+ signal to an FM signal so that it can be flexibly configured depending on the existing use of spectrum. In this way, DRM+ may be introduced into the FM frequency bands.

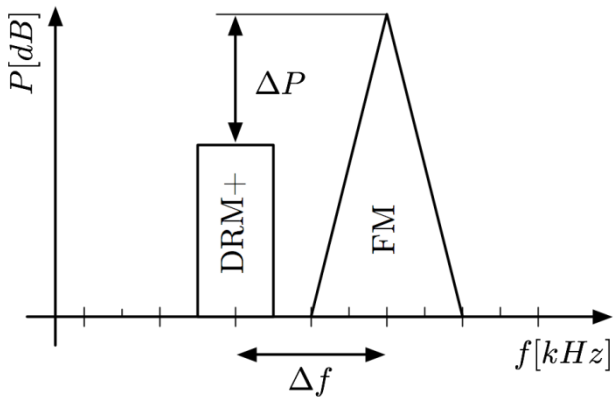


Figure1: Example configuration for DRM robustness mode E and FM signal

Figure A1-1 illustrates how the DRM+ signal can be placed closely above or below the existing FM signal. To guarantee the respective protection levels and audio quality of the FM signal, the carrier frequency distance Δf and the power level difference ΔP of the FM and the DRM+ signals have to be

planned accordingly. Δ*f* can be chosen according to a 50 kHz channel raster. Δ*f* >= 150 kHz is recommended. ΔP can be varied flexibly; however, a ΔP > 20dB is recommended for the minimum Δ*f* = 150kHz according to previous evaluations.

Looking at the heavily congested FM spectrum in Johannesburg, a proof of DRM+ not interfering with adjacent FM stations, would demonstrate the feasibility of the standard.

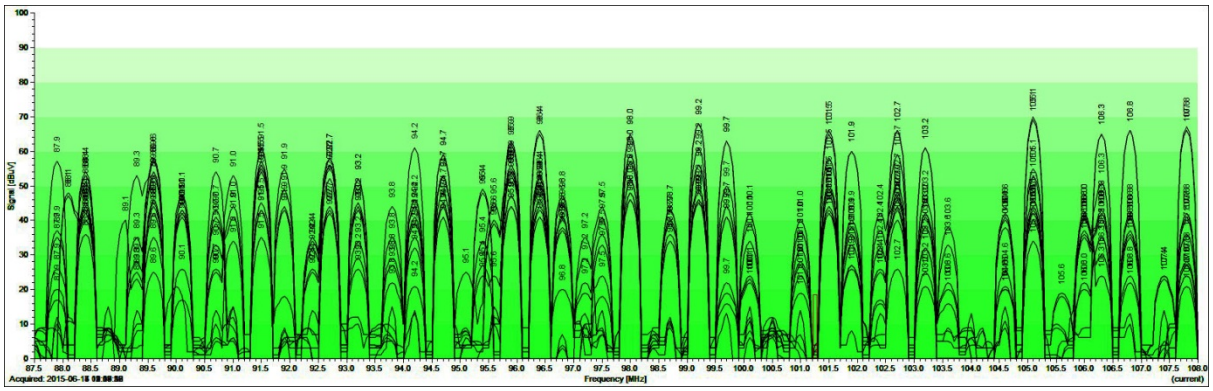


Figure 2: Overlay of Scans of the FM Spectrum in various parts of Johannesburg

Figure A4-1 confirms that there would be no space for another FM station in Johannesburg except for perhaps one or two low-power community radio stations with a very limited coverage area.

However, if one gap as the one that we have identified for our trial would work for DRM+ without interference in both ways, it would proof that there will be suddenly plenty of available digital spectrum in the FM Band, namely 16 allocations (marked in red) as per the below figure:

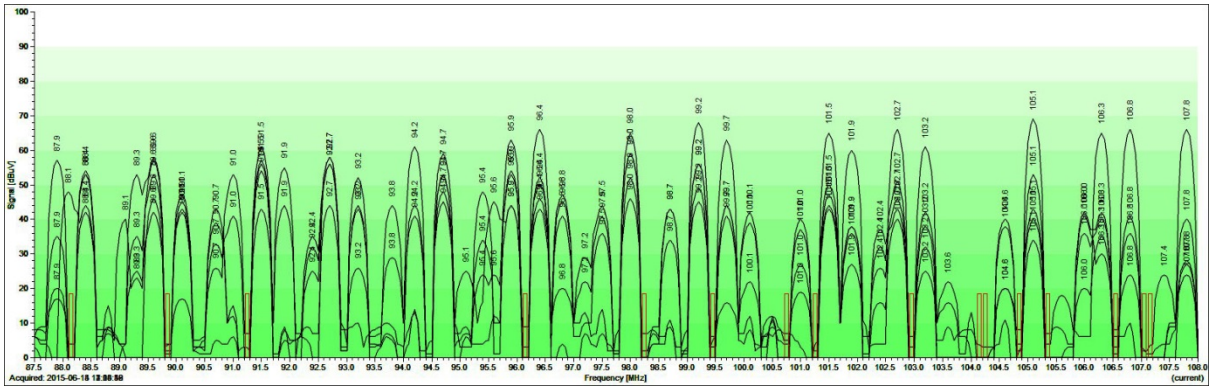


Figure 3: Possible DRM+ Allocations in the FM Band in Johannesburg

Considering at least 3 sound services per DRM+ signal, in this scenario up to **48 additional sound services could be added to the current FM spectrum in Johannesburg**. If going down to 200kHz@-10dB this number would even increase a lot more.

As a good candidate for such a frequency we have identified the frequency 101.25MHz as a possible candidate. It is situated between 101.0MHz (RSG Pretoria, 33kW ERP, distance: 56km) and 101.5MHz (RSG Johannesburg, 38kW, 3km distance) with a delta f of each 250kHz as shown in figure A4-4:

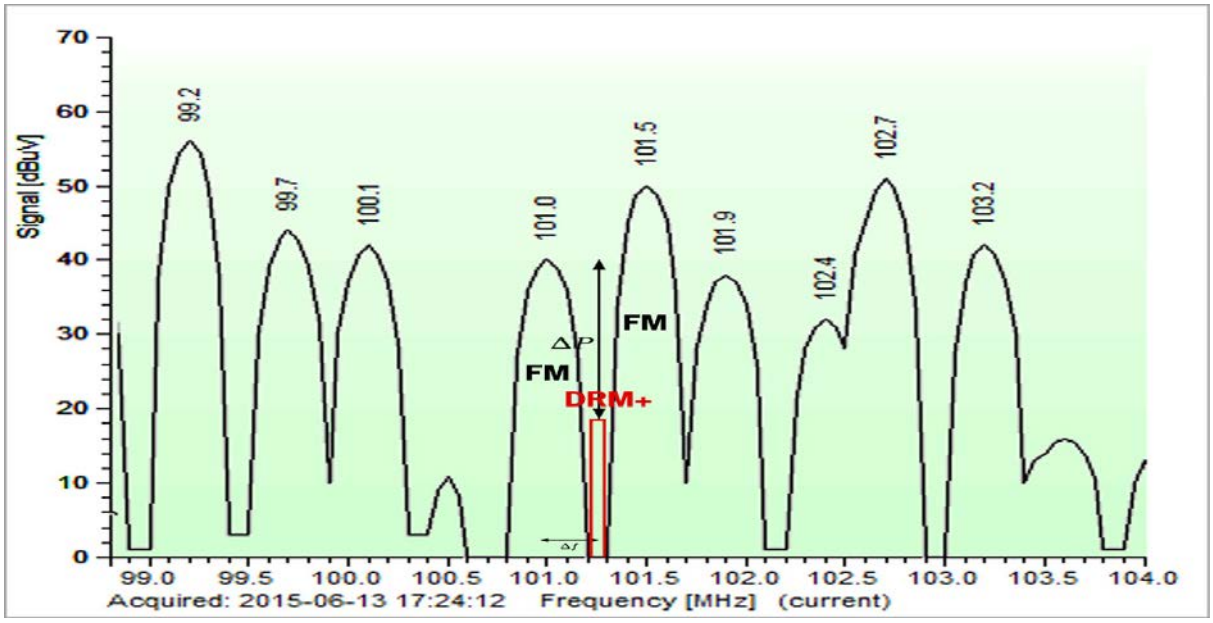


Figure 4: Our identified DRM+ allocation for the trial

None of the intermediate frequencies (101.2-101.4) are used otherwise within a radius of 160km. Currently we are broadcasting our FM signal from Rahima Moosa Hospital, Coronationville and intend to place our DRM+ transmitter (lent from BBC London) at the same location. This will also allow us to precisely compare the coverage of our own FM signal (Kofifi FM 97.2) with the DRM+ coverage.

4. Reasons for the Trial

The DoC and DTPS, as well as ICASA, SABS, and SADIBA, are currently looking at the two digital radio standards DAB and DRM. Both DAB and DAB+ have been tested by Sentech since 2006 and DRM in the AM Band (DRM30) has been tested by Radio Pulpit in 2014/2015 whereas **DRM+ has never been tested on the African continent yet**. Due to the assumed advantages and socio-economic benefits (see below) of the system, a trial of DRM+ was therefore highly recommended. This was also raised at the SADC BDM Conference on 17 March 2016 in Maseru and the CRASA Conference in June 2016.

DAB+ requires spectrum in VHF Band III, still being in use for terrestrial television. Also, as like in other parts of the world, all spectrum above 450MHz is considered to be used by IMT broadband services in the future which potentially could force DTT to be moved back into VHF Band III.

Then again, DRM+ can be operated in any frequency between 30 and 254 MHz today including VHF Bands I, II and III. VHF Band I is the only spectrum allowed for broadcasting in or close to the SKA, and the FM Band can potentially accommodate DRM+ signals without causing interference with existing FM stations. To prove evidence to this, both scenarios, frequencies in VHF Band I in a rural area in the Northern Cape close to the SKA and VHF Band II (FM Band) in a highly congested area – in this case the City of Johannesburg – have been selected for this trial.

Technically, this trial should give results with regards to coverage (4QAM and 16QAM) compared to FM, in both rural and urban environments. Also the FM Band DRM+ trial will provide information if there is any interference between DRM+ and FM in a real environment. Another aim will be the test of various digital receivers and give the opportunity to the local electronic industry to develop their own DRM receivers and test them with our signal.

5. Timeline of the Trial so far

- April 2015 — The idea of undertaking a DRM Mode E trial in Johannesburg was discussed at the SADIBA Digital Broadcasting Now Workshop in Johannesburg by WECODEC and the DRM Consortium
- June 2015 — Negotiations between the DRM Consortium, the BBC and WECODEC started
- September 2015 — The intended project was presented to an international audience at IBC
- December 2015 — An MoU was signed between BBC and WECODEC to undertake the trial
- April 2016 — The trial equipment was sent from BBC to WECODEC and WECODEC submitted a trial license application to ICASA
- May 2016 — The equipment was installed at our FM transmitter site in Coronationville
- June 2016 — The need for the trial was also confirmed at the 2017 CRASA workshop in Johannesburg
- August 2016 — Presentations were held by WECODEC at ICASA for further explanations
- September 2016 — WECODEC representatives undertook a travel to Europe (London, Berlin, Amsterdam, Hannover, and Zurich to verify the feasibility of the DRM system and its benefits for South Africa
- October 2016 — WECODEC presented a report with its finding of the Europe trip to ICASA
- January 2016 — A project manager was assigned to support the trial activities
- February 2017 — The trial license was issued by ICASA
- 1 March 2017 — The trial license became effective
- 10 March 2017 — The transmission officially started in presence of WECODEC team and ICASA staff members. First objective – no interference towards adjacent channels – was demonstrated and verified;
- 22 March 2017 — The trial project was presented at the German DRM Forum in Bonn;
- April-May 2017 — Mobile measurements were taken; various software updates on the RF Mondial Monitoring Receiver had to be made; various consumer receiver setups were tested and software improved as consequence of the trial; trial was presented at the DRM Consortium General Assembly in Zurich;
- June 2017 — Localization of Journaline data services; further tests with consumer receivers were performed; this interim report was produced.

6. Objectives of the Trial

The objectives of the trial in details are:

- To verify that DRM if operated in the FM Band will not interfere with existing FM broadcasts;
- To evaluate if FM broadcasts adjacent to a DRM signal in the FM Band have an impact on the DRM signal;
- To compare the real DRM signal propagation with prediction calculations;
- To confirm proposed benefits of the DRM system in the VHF Bands, in particular:
    - Spectrum efficiency;
    - Power savings compared to FM;
    - Sound quality – specifically of the new codec xHE-AAC;
    - Usefulness of data services with specific focus on Journaline;

    - Signal propagation in Band I;
    - Potential for educational services, community and public/commercial radio;
    - Evaluation of receivers that are available and can be used by consumers;
- To compare different robustness modes (4QAM vs 16QAM);
- To compare the propagation characteristics of DRM and FM in both mobile and fixed indoor environments and verify the official planning parameters.

7. Our Transmission System for the Trial

As a loan from the BBC, WECODEC has received a complete DRM broadcast system, comprising of

- 1x Fraunhofer Content Server;
- 1x RF Mondial A/D Interface;
- 1x RF Mondial DRM+ Modulator;
- 1x Nautel Exciter/Transmitter;
- 1x Nautel 2.5kW Power Amplifier;

and the RF-SE12 Monitoring Receiver. In our first configuration we installed the system including the receiver to setup and test the functionality on a dummy load (picture: May 2016).

Later we had to remove the monitoring receiver as we would need it as receiver for our mobile measurements as we were not supplied with a second receiver for the measurements.

2 months later, also the satellite dish and receiver to receive BBC World Service as another audio source for the trial was installed. The final setup is as follows:

🡐 FM Power Transmitter for Kofifi FM 97.2

🡐 FM Exciter for Kofifi FM 97.2

🡐 STL Receiver for both Kofifi FM 97.2 and DRM
🡐 RDS Encoder for Kofifi FM 97.2
🡐 BBC C-Band Receiver

🡐 DVD Player for third DRM Audio source

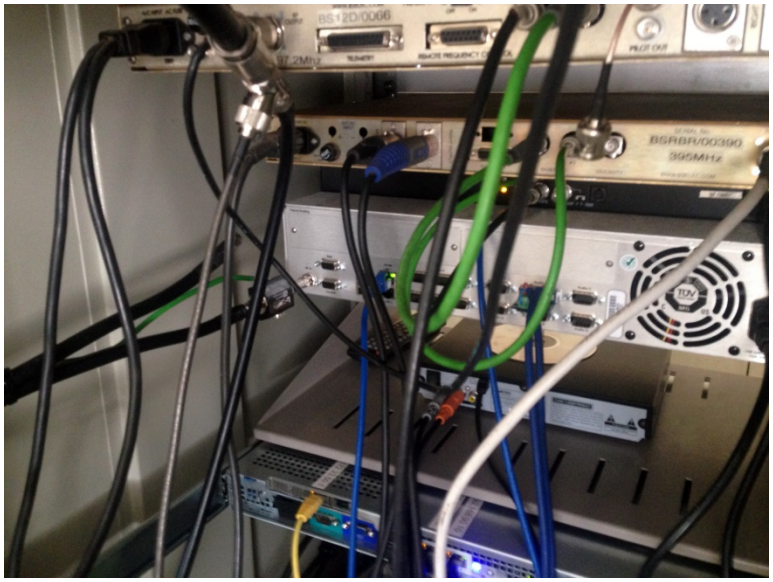
🡐 Content Server for DRM System
🡐 DRM Modulator
🡐 Audio A/D Converter

🡐 DRM Exciter

🡐 DRM Power Transmitter

(Front view of transmission system).

Back view of the transmitter rack and the 4-dipole antenna system with BBC C-Band reception dish:



<u>The transmission chain and equipment in detail:</u>

STL Receiver Channel 1	BS Electronics, Cape Town, South Africa
C-Band Receiver Channel 2	XDS PRO-40, X -Digital Systems, San Diego, CA, USA
DVD Player Channel 3	SINOTEC, Midrand, South Africa
Connectivity STL to A/D converter:	Balanced Stereo Audio over 2x XLR
A/D Converter:	RF Mondial, Germany
Connectivity to Content Server:	UDP over IP over Ethernet
Content Server	Fraunhofer IIS, Germany
Connectivity to DRM Modulator	MDI over IP over Ethernet
DRM Modulator	RF Mondial, Germany
Connectivity to VHF Band II Exciter	Baseband over AES/EBU over XLR
VHF Band II Exciter	Nautel, Canada
VHF Power Transmitter	Nautel 2500, Canada
Connectivity to Combiner	Coaxial 7/8’ EIA to 7/8’ EIA
Combiner	97.2MHz FM / 101.25MHz DRM 7/8’ EIA to 1 5/8’ flange
Lightning Protector	BS Electronics, Cape Town, South Africa – 3x 7/16’ DIN
4-way Antenna Splitter	RF Industries, Alberton – 7/16’ DIN to 4x N-Type
4x VHF Band II Antennas	RF Industries, Alberton, South Africa
Internet connectivity	iBurst

<u>Technical Transmission Specifications:</u>

RMS Power Range	64-2500W RMS
RMS Typical Power	175W RMS
Antenna Gain	6dBd
Cable/splitter loss	approximately 1.4dB
Typical ERP	500W
Transmission Frequency	101.25MHz
Modulation; Bandwidth	DRM Mode E; 96kHz

Antenna System and Location:

Antenna system	4-stack vertical dipole
Co-ordinates	27E58'20'' / 27S11'23''
Physical address	Rahima Moosa (Coronation) Hospital, Fuel Road, Westbury
Antenna height	60m
Antenna height above sea level	1720m
Polarization	Vertical
Beam width	Omni-directional

DRM Parameters:

DRM Mode	E
Modulation	4QAM/16QAM (Typical: 4QAM)
Protection Level (from 0 to 3)	1 (0.33)
Bitrate	49680 bps (typical)
Services	1. Audio: KOFIFI DRM 101.25, xHE-AAC mono, 14320bps 2. Audio: BBC, xHE-AAC mono, 12320bps 3. Audio: (various), HE-AACv2, parametric stereo, 19360bps 4. Data Services including Journaline Demo: 3680bps

License Details:

License Number	001/Trial/DRM+/WECODEC/Nov2016
Issued on	02 February 2017
To	Westbury Community Development Centre Trust
Effective from	01 March 2017
Valid until	31 October 2017
Signal Distributor	BluLemon
Geographic Coverage Area	Westbury, South of Johannesburg, Sophiatown and surrounding areas within the City of Johannesburg Metropolitan (and in Carnavon in the Northern Cape) as set out in the attached technical specifications in Schedule B2 of the license (Appendix)
Designation of Emission	96K0X7EXF
Frequency Stability	2kHz
Spurious Emissions	60dB/1mW

8. Our Receiving Units and Setups for the Trial

As part of the loan equipment provided by the BBC, an RF Mondial DRM Monitoring Receiver was dispatched to WECODEC together with the first lot of broadcast equipment in April 2016. This receiver was used to setup and test the transmission equipment on a dummy load (provided by Carlos) prior to real field trials. Once the system was initialized and considered functional, the receiver was removed from the transmission site and prepared for installation in our measurement vehicle. As a replacement we have equipped the transmitter site with a RTL-SDR based USB receiver operated at a PC with the open source software SDR Sharp.

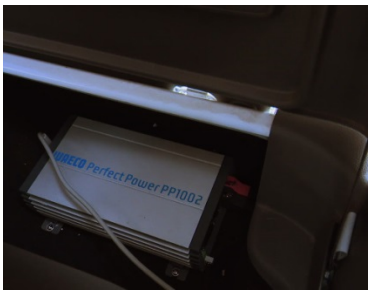
Besides this professional receiver, various low-cost consumer devices (to operate in conjunction with PC's, laptops, tablets or smart phones) have been acquired and are being tested in this trial.

8.1 Our Drive-By Measurement Vehicle

Contributed by KMG, WECODEC is using a Volkswagen Caddy for the drive-by measurements.

Sent in for preparations

Car antenna



DC/AC Inverter to supply 230V

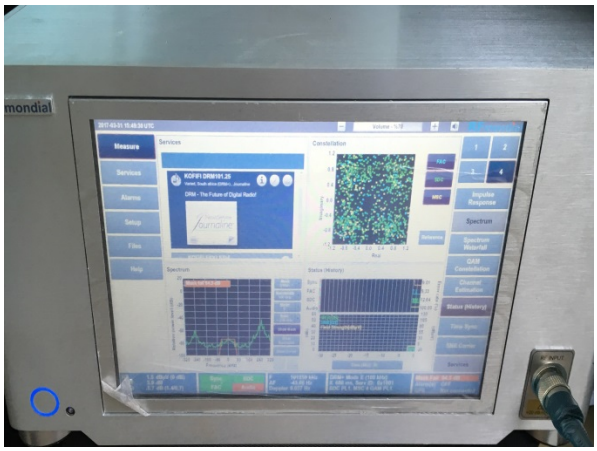
Magnet Antenna

The car was equipped with a generic FM car antenna to simulate real-life reception conditions. As some equipment including the RF Mondial monitoring receiver operates at 230V current, we also had to equip the car with a DC/AC inverter.

For accurate field strengths and SNR/MER measurements a Kathrein magnet antenna was used as reference.

8.2 RF Mondial Monitoring Receiver

Today, the RF Mondial RF-SE12 is the world's only DRM+ capable calibrated reference monitoring receiver. It is built in a 6 units 19 inch aluminium case with integrated LCD touch screen but can be fully controlled via a flash capable browser interface. As there is currently no compatible flash version available for iOS or Android, we had to acquire a Windows 10 tablet computer.



The RF Mondiale receiver original display

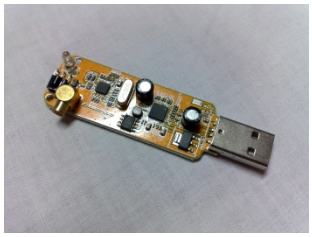
The receiver controlled by our Prestigio tablet

8.3 STL-SDR Receivers

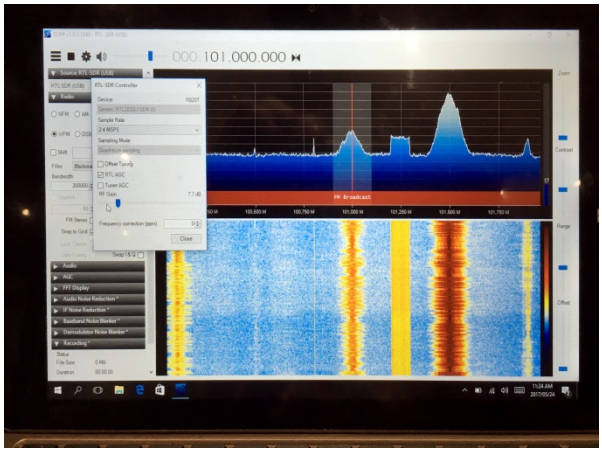
As we are still waiting for the "Titus II", a DRM capable consumer receiver, WECODEC decided to investigate the possibility of using so-called "RTL-SDR" receivers for our trial.

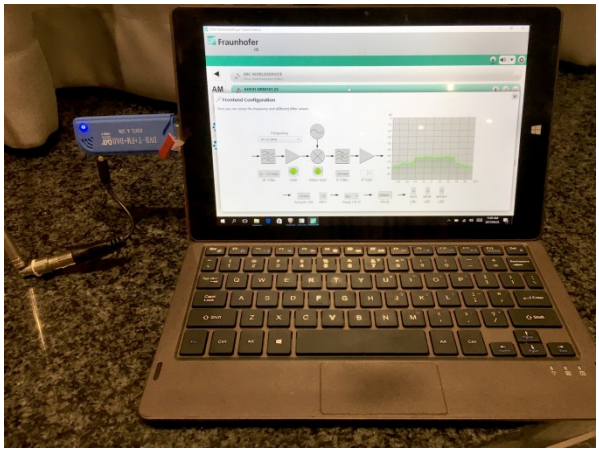
RTL-SDR is a very cheap software defined radio that uses a DVB-T TV tuner dongle based on the Realtek RTL2832U chipset. With the combined efforts of Antti Palosaari, Eric Fry and Osmocom it was found that the signal I/Q data could be accessed directly, which allowed the DVB-T TV tuner to

be converted into a wideband software defined radio via a new software driver. As common applications also include FM radio, tuner chipsets used in such DVB-T dongles are also capable of tuning into the FM Band. Typical tuner chipsets are the Elonics E4000, Fitipower FC0012/13, or Rafael Micro R820T/2.


A typical DVB-T USB-Dongle.

The RTL-SDR solution can work with various software programs including the functionality of playing FM radio or display the spectrum. Fraunhofer IIS in Erlangen/Germany has developed the so-called Multimediaplayer software which is capable of decoding a DRM signal from an RTL-SDR dongle on any Windows PC, laptop or tablet. This solution allowed us to start testing consumer suitable DRM scenarios for the community and elsewhere.


"SDR-Sharp" showing the spectrum and our signal


Fraunhofer Multimediaplayer decoding our signal

<u>All measurement equipment and tools in detail:</u>

Vehicle	Volkswagen Caddy
Car Antenna	Standard car whip antenna fitted by Soundwaves
Inverter	Perfect Power PP1002, by WAECO, Germany
Reference Antenna	K 510 351 cut to 75cm, 50Ω, by Kathrein, Germany
Monitoring Receiver	RF Mondial RF-SE12 – DRM+ version
GPS Receiver	NL-402U by NAVILOCK, attached to the monitoring receiver
Tablet (used for remote control of RF Mondial receiver as well as SDR receiver)	MULTIPAD VISCONTE V 3G by Prestigio, Russia (sourced in South Africa)
RTL-SDR Receivers	1. DVB-T Stick, with FC0012 tuner by Trekstor, China 2. DVB-T Stick, with R820T2 tuner, no-name, China
RTL-SDR Software	1. SDR-Sharp by Youssef TOUIL, V. 1.0.0.1540 2. Drivers: Zadig by Peter Batard (GPLv3), V. 2.2.689 3. Multimediaplayer by Fraunhofer IIS, Germany 4. RTL-TCP Rev. e3e6ee23 by Osmocom, Germany

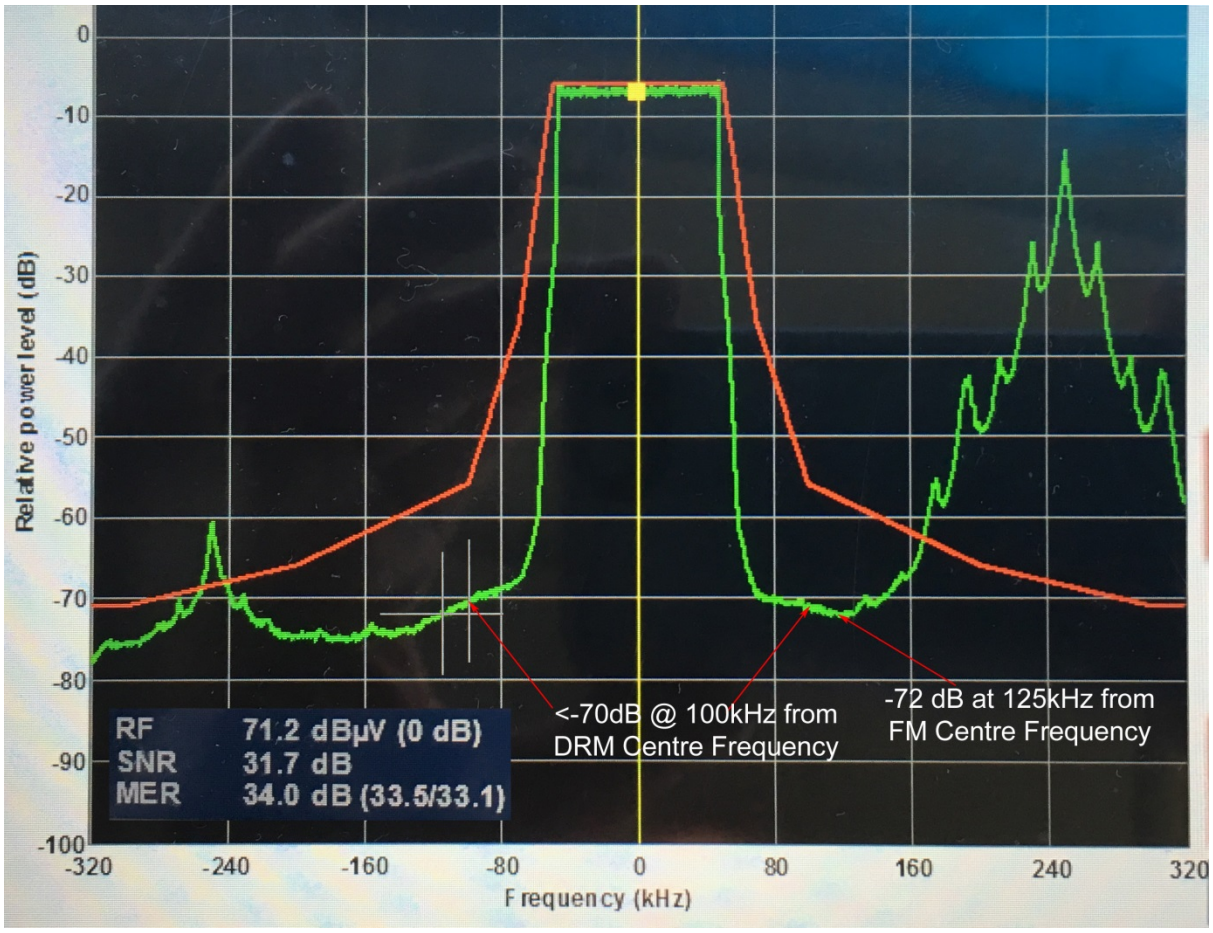
9. Methodology and Results so far

Phase Zero

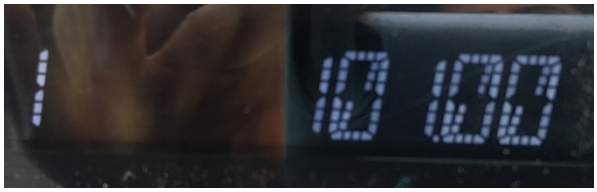
Our first objective as mentioned earlier was to proof that no harmful interference to existing FM channels would occur from our DRM+ transmissions. It was assumed that the highest possibility of such interference would be noticeable in close distance to our transmitter site. We therefore measured field strength and spectrum mask conformity right in front of the transmitter site as well as tune into both adjacent channels with different FM receivers and listen if the audio quality was impacted as well as test confirm that RDS information is not impacted either.

Further measurements within 2.5km of the transmitter were done and at locations where one or both adjacent signals were weak due to terrain or other reasons, the DRM transmitter was remotely switched off via TeamViewer access to identify if the impact of the FM signal was caused or partly caused by the DRM transmission. These tests were done within the first week of operation to ensure that no harmful interference was emitted from our trial.

With regards to the visual test, in front of the transmitter site with a field strength of 71.2dBµV (80 dBµV/m: antenna factor=8.2 @ 101.25MHz/50Ω) the DRM signal was clearly within the limits of the ITU conform spectrum mask that proposes the signal to be at a relative power level of-56dB at +-100kHz from the centre frequency (our signal was <-70dB on both sides). At the physical end point of the FM signal at +-125kHz where the stronger adjacent signal at 101.5MHz came down to -72dB which was not exceeded by our DRM signal either:



Audio was then measured with JVC, Pioneer, and Jeep car radios:



No interference caused by the DRM+ transmission was audible to both adjacent FM channels. Audio/Video recordings have been captured and are available on the attached DVD.

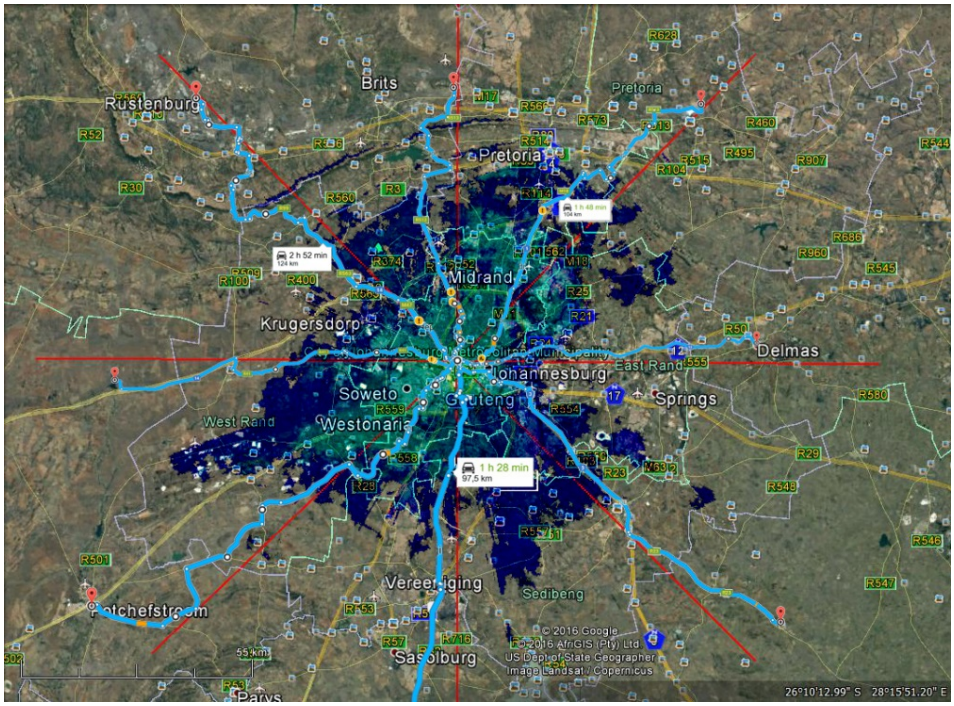
A weak audio on 101.0MHz was e.g. noticed at Westdene Dam at 2.3km distance from the transmitter. The measurement vehicle was stopped in that position and the transmitter was remotely switched off. There was no change to the audio signal noticeable.

These tests were undertaken with our measurement vehicle VW Caddy and Pioneer radio and were repeated with Honda Brio and JVC radio as well as a Jeep Wrangler on its built-in Jeep car-hifi system. All tests confirmed that no harmful interference to the adjacent FM channels were evolving from our DRM+ transmissions.

In coordination with ICASA it is planned at a later stage to repeat this test at modified DRM frequencies closer to the adjacent channels as recently in Indonesia it was demonstrated that even at a Δf of only 150kHz no interference to FM transmissions were noticed.

<u>Phase One</u>

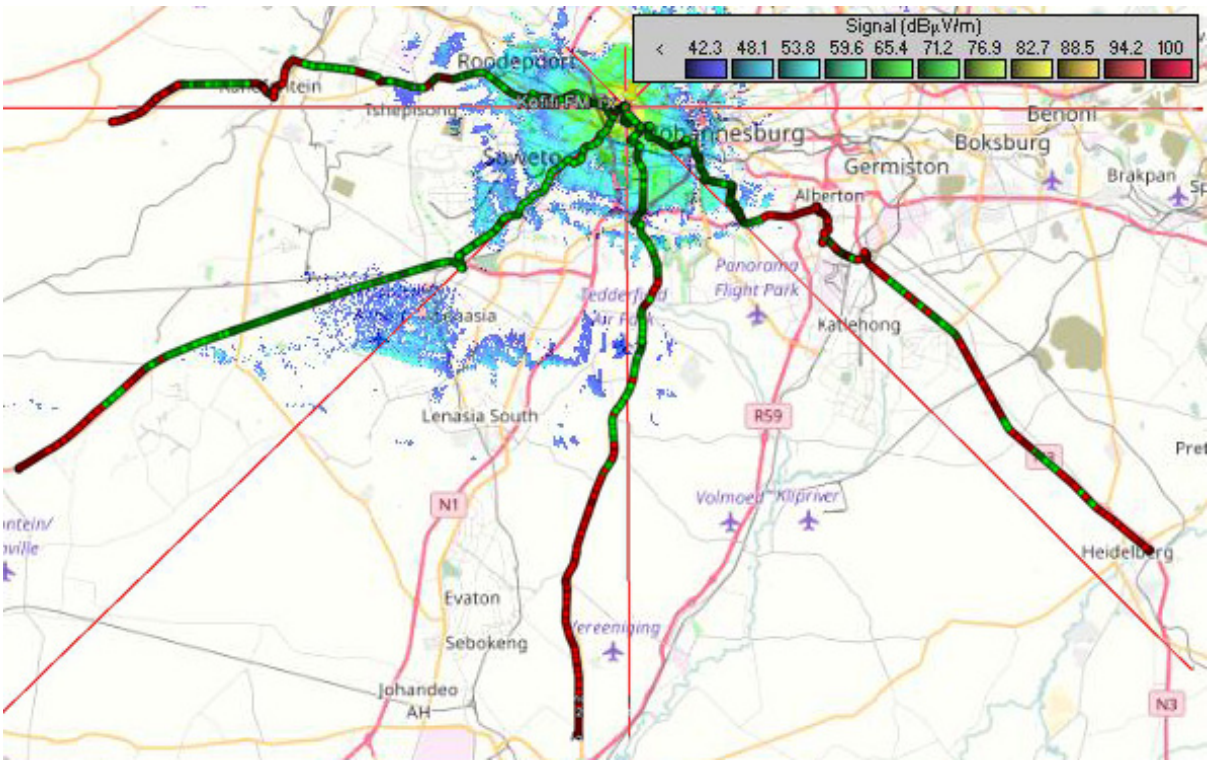
Within the first 2 months, drive-by measurements were conducted with our vehicle using the RF Mondial Monitoring Receiver connected to the Kathrein antenna, at a height of 1835mm from the ground. For these measurements initially 8 radial routes from the transmitter site in N, NE, E, SE, S, SW, W and NW directions have been planned.



Possible planned routes vs maximum estimated coverage prediction

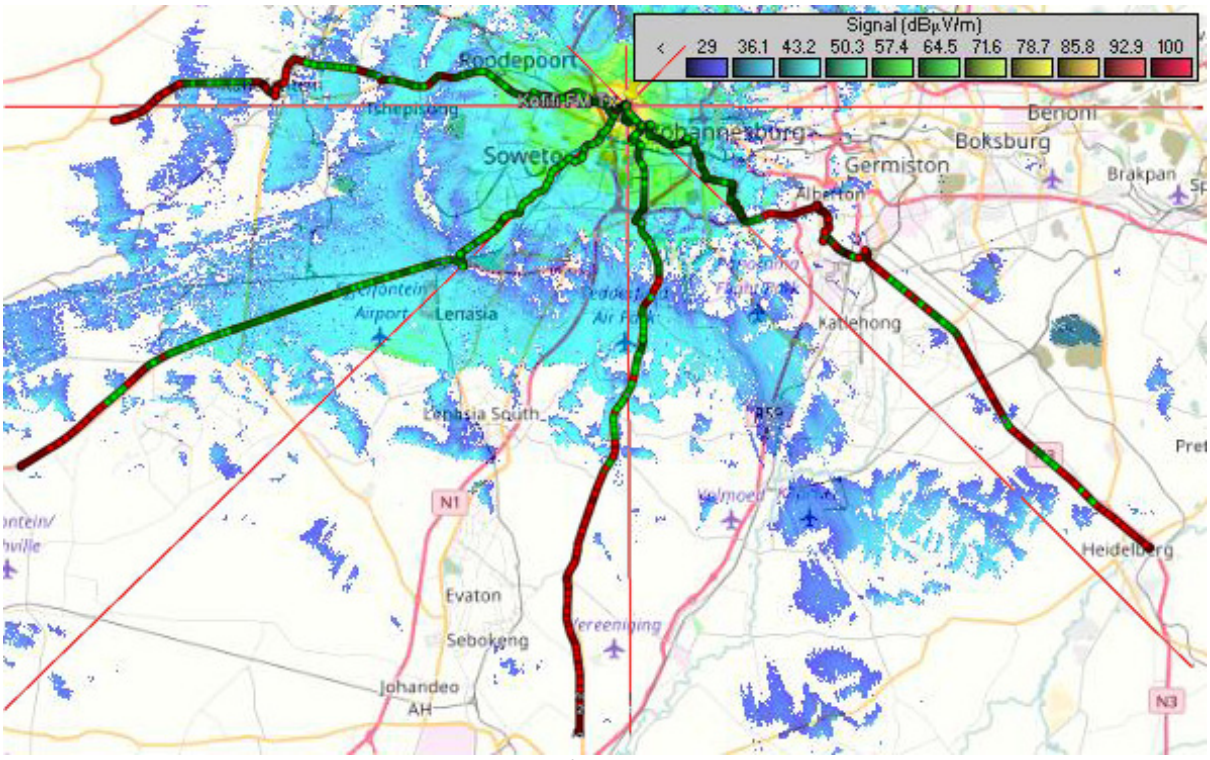
Measurements were conducted by driving outwards on each radial with the all service channels configured on our standard modulation setting (4QAM) up to the point where complete audio failure occurred plus 5km. Once audio failure detection was confirmed, the same route was measured in the opposite direction back to the transmitter, with the MSC configured to the higher modulation setting (16QAM). This measurement sequence was repeated for 4 of the planned radial routes so far (SE, S, SW, and W) that are particular to our license. The remaining 4 routes will be examined once additional receiver equipment has been installed. The transmitter was configured to transmit a DRM+ signal at 175W RMS (500WERP) during the coverage measurement exercises. During such measurements the built-in car-hifi system as a second receiver was tuned to 97.2MHz in order to have a permanent comparison between the analogue and digital signals originating from the same site. This was to verify if signal losses are specific to the DRM signal or affected both signals consequent to terrain characteristics or interferences impacting the whole band. It was recorded that almost in every situation there was a correlation between the FM audio and the DRM MER with a non-relevant count of abnormalities.

According to ITU-R BS.2214-1 (07/2015) *(Planning parameters for terrestrial digital sound broadcasting systems in VHF bands)*, the minimum field strength for mobile reception at a location probability of 99% is defined as 42.27dBµV/m for 4QAM and 1/3 FEC and 49.57dBµV/m for 16QAM and 1/2 FEC. However, the results from our 4 radial mobile drive-by measurements demonstrate a comfortable overhead according to those parameters and there is not a single spot of predicted coverage that was not measured error-free:



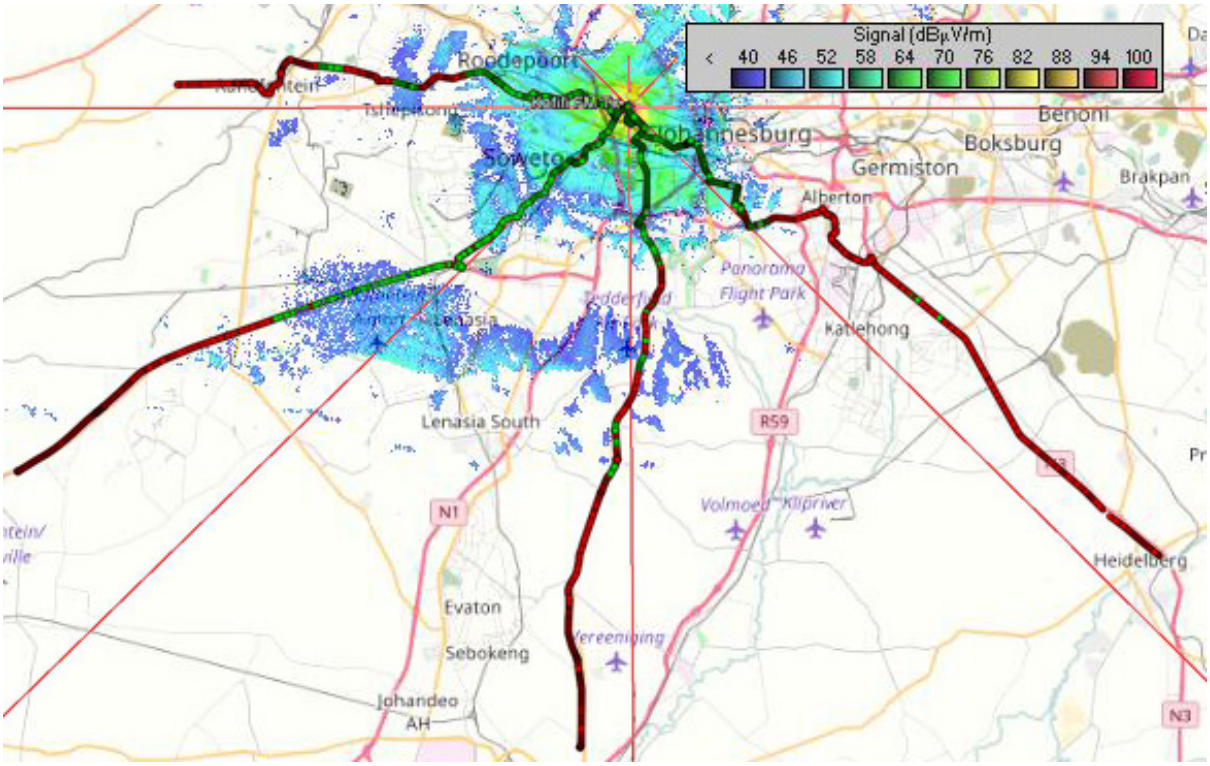
Drive-by mobile measurements at 4QAM and 1/3 FEC against coverage prediction at 99% location probability and a threshold of 42.27 dBµV/m

The measurements show an average overhead of roundabout 13dB that can cater for worse real reception conditions such as poor quality aerials and receivers or man-made noise interference.



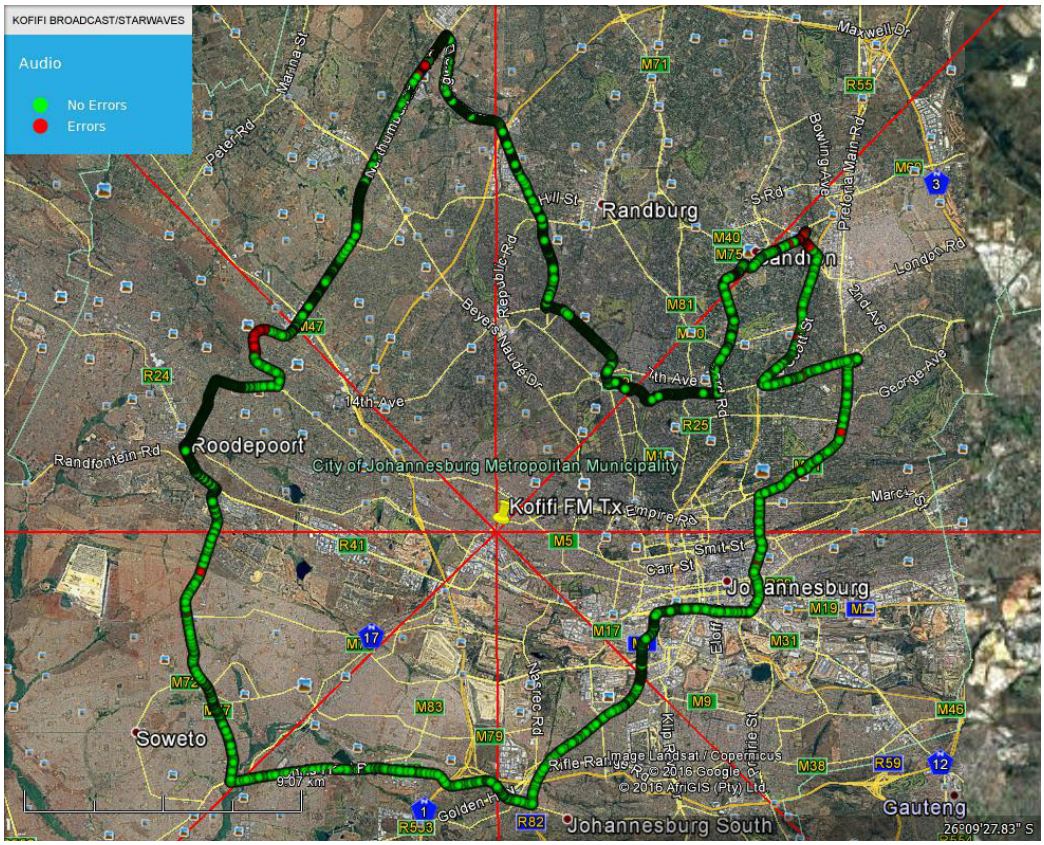
Drive-by mobile measurements at 4QAM and 1/3 FEC against coverage prediction at 99% location probability and a threshold of 29dBµV/m

The Drive-by mobile measurements with 16QAM and 1/3FEC show the expected higher sensitivity as reception was at 100% only a 40dBµV/m threshold. As planning parameters of 49.47dBµV/m are for 1/2FEC and supposed to be lower for 1/3FEC, the overhead is lower (between 6 and 8dBµV/m).



Drive-by mobile measurements at 16QAM and 1/3 FEC against coverage prediction at 99% location probability and a threshold of 40dBµV/m

Measurements were also taken randomly at various routes on a daily routine in order to understand strengths and weaknesses of the system such as vulnerability to specific terrain or interference. Also during these measurements the car-hifi system was tuned to 97.2MHz for comparison purposes.



A map resulting from a round trip in an average distance of 10km around the transmitter site. The signal was blocked behind Noorde-krans hill where also no FM signal was audible.

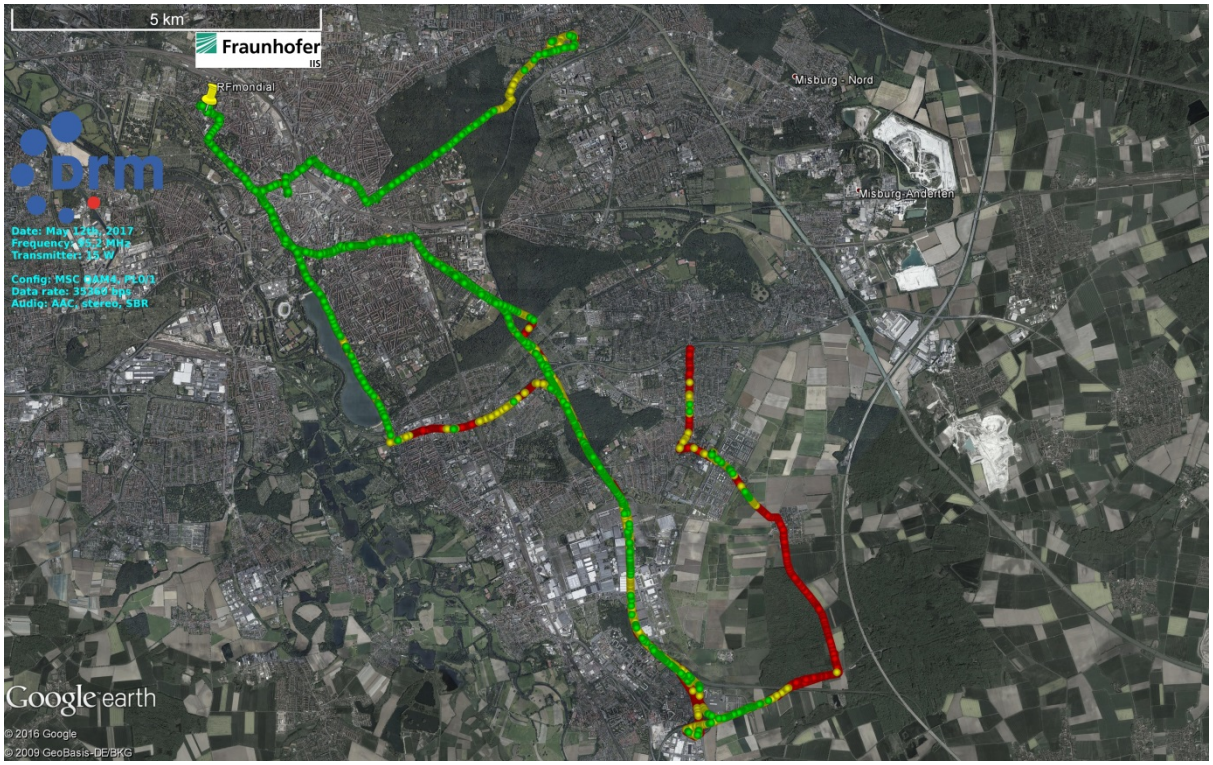
Services were monitored and measured on all the planned and random routes. Whenever measurement incidents (e.g. loss of audio, decode-ability, recovery of audio etc.) were experienced the coordinates, measurement parameters and incident details were logged and noted.

<u>Phase Two</u>

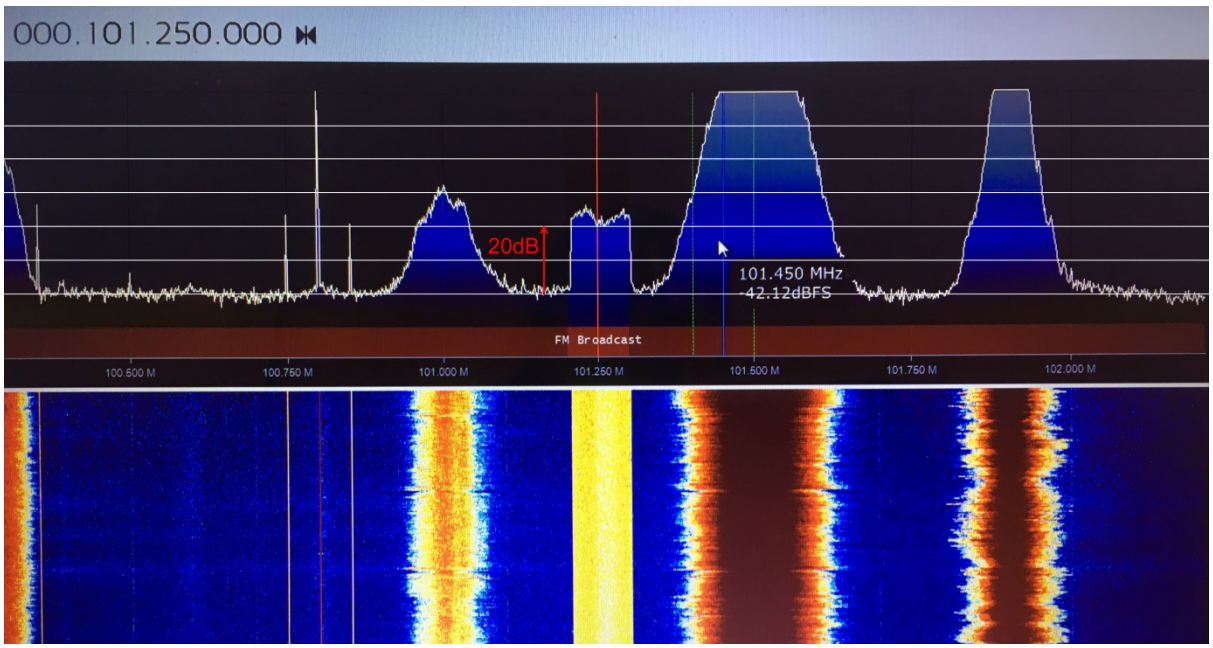
In the second phase we intend to include consumer receivers and let community members and other stakeholders experience the functionality of the DRM broadcasts and after a specific testing period conduct a survey amongst the trialists to capture their evaluation and impression of the system. This should help to evaluate the usefulness of the DRM system including data services in a practical environment.

For this purpose a number of RTL-SDR receiver dongles will be used at various customers' locations and connected to their existing PC's, notebooks or Windows™ tablets and Fraunhofer's Multimedia-Player software will be installed for system evaluation.

In preparation for this test, various RTL-SDR based receiver solutions have been tested in cooperation with Fraunhofer Institute and RF Mondial in the second week of May 2017 in Hannover, Germany, where a live DRM+ signal is present at 95.2MHz. For the drive-by tests in Hannover with 3 different receivers, a software that specifically coded by Fraunhofer for this test was used to capture signal information as shown in the map below:



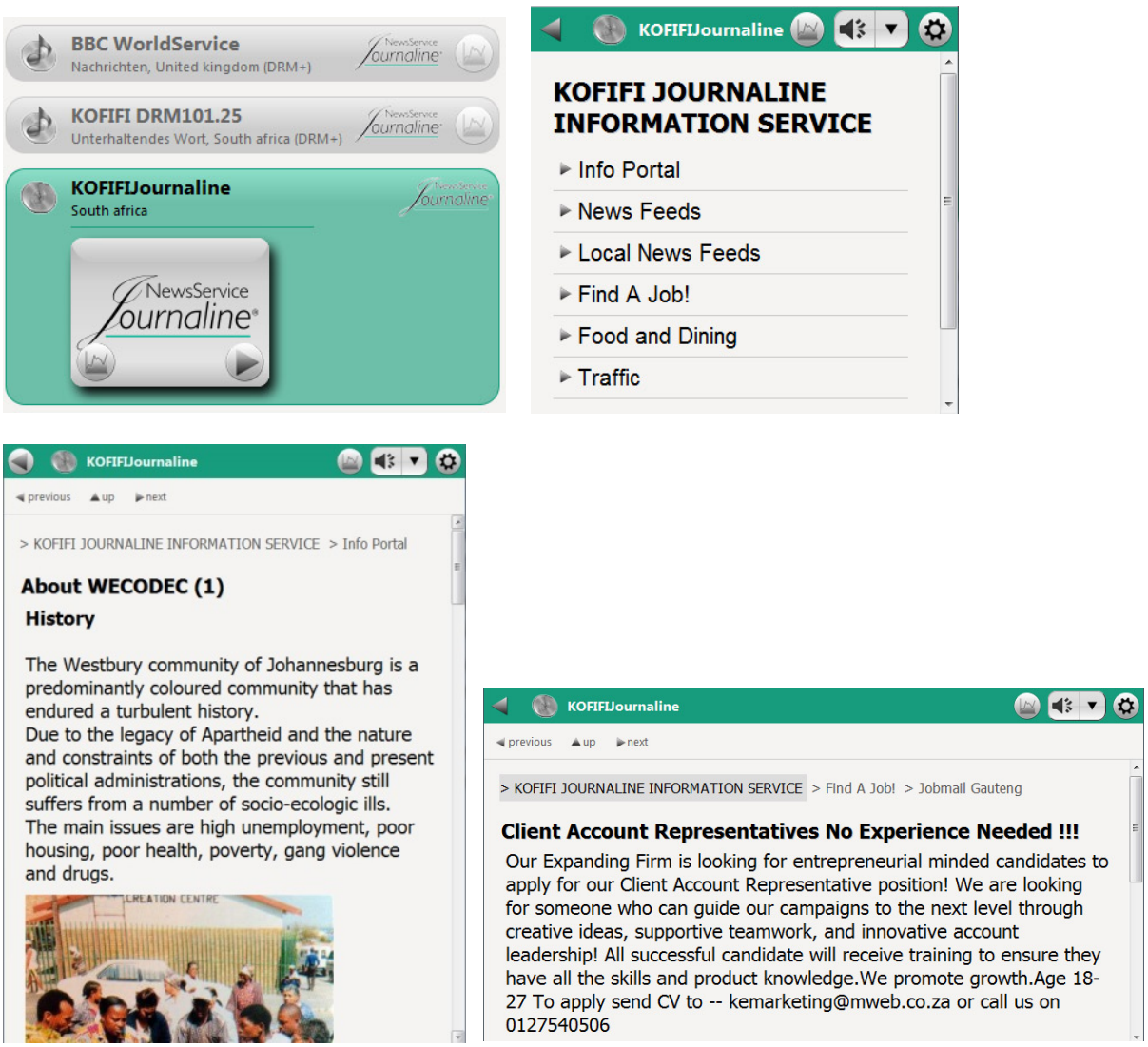
The findings of these tests in Hannover helped to improve the Fraunhofer Multimediaplayer software to its current state. Since then, a few mobile and fixed tests have been undertaken in Johannesburg with two different RTL-SDR based receiver sets. As AGC functionality still needs to be improved, the mobile reception capabilities of such solutions are still limited and so far only function reliably within a relatively close distance to the transmitter (3-5km). However, at fixed locations with the possibility of manually tuning the input gain to an optimal level, the results so far are very close to the results from the RF Mondial monitoring receiver. Even in critical indoor locations with poor FM reception a crystal clear reception of the DRM signal was possible as shown in this screenshot:



SDRSharp with RTL Dongle and small whip antenna at critical indoor location: SNR>20dB.

Preparations for the community members' participation in and evaluation of the trial are ongoing. Some live content (updated every 60 minutes) has been integrated with the Journaline service, including an Info Portal with information about WECODEC, Kofifi FM and other stakeholders, DRM, Government and country information; National and local News including lifestyle and sports; various Job Portals ("Find a job via Journaline") including a skills portal and more.

This information offering will be increased and updated on a regular basis and optimised in dialogue with the community members who will be testing the service. Towards the end of the trial period we expect at least 50 community members to have evaluated the system and provided feedback on a questionnaire that will be attached to the final report.



Screenshots of the WECODEC/Kofifi Journaline Information Service

10. DRM+ in VHF Band I (Phase 3)

According to the National Radio Frequency Plan 2013 of South Africa, published in Government Gazette 36336, a lot of the spectrum known as VHF Band I (47-68MHz) is still allocated for broadcasting:

ITU Region 1 allocations and footnotes	South African allocations and footnotes	Typical Applications	Comments
47-68 MHz BROADCASTING	**47-50 MHz** BROADCASTING LAND MOBILE 5.164	CT0 Cordless Telephones MTX (49.67 – 49.97 MHz)	Paired with 46.61 – 46.97 MHz. Radio Frequency Spectrum Regulations (Annex B) (GG. No. 34172, 31 March 2011).
	50-54 MHz AMATEUR 5.169	Wireless microphones (53 – 54 MHz)	Radio Frequency Spectrum Regulations (Annex I) (GG. No. 34172, 31 March 2011) Radio Frequency Spectrum Regulations (Annex B) (GG. No. 34172, 31 March 2011)
	54-68 MHz BROADCASTING FIXED 5.171 MOBILE except aeronautical mobile 5.171	Government Services Model control (54.45 – 54.55 MHz) Single Frequency Mobile (54 – 54.325 MHz) Mobile 1 BTX (54.325 – 54.45 MHz) Mobile 2 BTX (55.45 – 56.85 MHz) Single Frequency Mobile (56.85 – 58.5 MHz) Mobile 2 MTX (58.5 – 59.9 MHz) Mobile 1 MTX (59.9 – 60.025 MHz) Sport Stadium Communications (62.8 – 62.85 MHz) National Emergency Alarm Radio (NEAR) (66 – 68 MHz)	Radio Frequency Spectrum Regulations (Annex B) (GG. No. 34172, 31 March 2011) Paired with 59.9 – 60.025 MHz Paired with 58.5 – 59.9 MHz Paired with 55.45 – 56.85 MHz Paired with 54.325 – 54.45 MHz
5.162A 5.163 5.164 5.165 5.169 5.171			

Extract from SA National Frequency Plan of South Africa

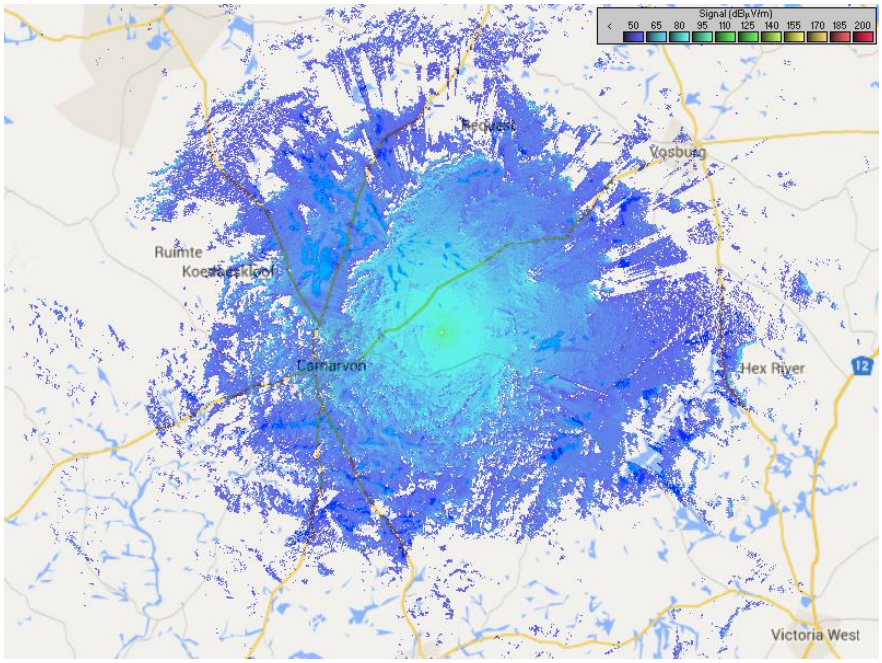
Specifically, frequency spectrum between 63 and 66MHz is not assigned for other than broadcast services and could be considered as available spectrum for digital sound broadcasting.

The ECC (Electronic Communications Committee within the European Conference of Postal and Telecommunications Administrations (CEPT)) has also looked at its Report 117, *"MANAGING THE TRANSITION TO DIGITAL SOUND BROADCASTING IN THE FREQUENCY BANDS BELOW 80 MHz"*, Athens, February 2008 and revised Gothenburg, September 2010, at the use of the lower frequency broadcast bands – below 80MHz – for digital broadcasting to national, local and community audiences. Included are the LF, MF, 26 MHz (HF) bands and VHF Band I.

DRM+ has been developed to operate within this spectrum and has been approved by ITU. As in the Northern Cape close to the SKA area (besides half of the FM band) it actually is the only radio frequency spectrum that is permitted to carry broadcast signals to the marginalized communities in that area which otherwise would remain disconnected from the universal access to information, we have chosen this area for our Band I DRM trial.

Sentech is currently operating an FM sound broadcast from Carnarvon/Wildeperdeberg but only broadcasting 3 radio stations which are KFM, RSG and SAFM. Opening up only 1MHz of VHF Band I spectrum (e.g. 63-64MHz) would provide space for 30 radio channels plus 10 independent data services such as traffic and weather information; news, health and educational Journaline services, or even basic news and even educational video services based on diveemo video. It could also accommodate an emergency warning system and in the future replace the analogue NEAR system which would vacate even more spectrum for future usage such as digital radio or mobile TV. An assignment of 3MHz (**63-66MHz**) would allow for **90 sound and 30 individual data services** capacity.

Due to possible sky-wave interference, broadcasting within Band I but should be above 63MHz which is known as the “magical split” from where no sky-wave propagation has been discovered. Therefore we have applied for and granted the frequency of 64.0MHz which is central in the proposed future Digital Radio Band of 63-66MHz. The transmitter will be located at Sentech’s Carnarvon site (22°22'29''S/30°54'14''E). The sub-project that we call “Digital Karoo” will be done in co-operation with Sentech, Ulwazi FM and Radio Gamkaland (the two closest community radio stations in the area). As Band I has not been in use for broadcasting for a long time sourcing adequate equipment was a greater challenge than expected. However, we have managed to source a suitable transmitter as well as a content server license and are currently finalizing the design of the full equipment chain that also takes affordability into account. Trial Phase 3 will therefore at earliest commence from August 2017.



Predicted Coverage Map of the Karoo-DRM+ Multiplex

11. Benefits

Many benefits as described below are mandatory by the Object of the ECA (Section 2):

Efficient usage of spectrum as a national resource

Since the initial efforts of introducing digital broadcasting in the 1980’s, the world has experienced numerous “revolutions” of information technology. Even the digitization plans from the ITU Geneva conference in 2006 had to be revised as radio frequency spectrum has become one of the most relevant natural resources on earth and different stakeholders are claiming utilization of the same.

This is a big challenge for both policy makers and regulators as they have to protect the interest of the public as well as provide an optimal environment for economic growth. Obviously these challenges are different for each country and economy due to their individual developments of the ICT sector and many other parameters. E.g. terrestrial television spectrum is less relevant in countries that have national cable coverage. But their economic viability is also dependent on general factors such as population density and terrain properties. In conclusion it can be said that in each economy, the most efficient utilization of radio frequency spectrum is paramount.

Common for all economies worldwide is that the ICT sector requires radio frequency spectrum in order to efficiently deliver universal access of information to the citizens. Wasteful usage of

spectrum will have a negative impact on this requirement, the growth of the sector, and consequently the entire GDP as such. In this light, the approach of DRM+ to fit into existing spectrum such as the FM band will allow for the most efficient usage of that spectrum and no extra spectrum bands that would be needed for other applications (such as e.g. VHF Band III) would be wasted.

With regards to VHF Band I, a review of its utilization by digital radio is long overdue. The band has not been used for analogue television broadcasting for reasons that are specific to disadvantages that analogue broadcasting develops in those bands (e.g. the frequency/signal bandwidth ratio is very low) but would now be overcome by the properties of the digital signals.

The ECC of 2008 concluded: "The greater quality and versatility of the DRM+ system would suggest that this was the preferred option for Band I. Band I is not at present, formally available for DRM+ (or DRM30) transmissions although individual administrations could give the relevant authorisation. With this in mind there are a number of regulatory instruments that would have to be put in place before widespread deployment. It is proposed that the CEPT considers revising the ERC Report 25 (the ECA Table) in the part 47-68 MHz to permit the introduction of digital sound broadcasting in this part of the spectrum (Band I)".

Stimulate South African Consumer Electronics Industry

The immediate presence of digital radio signals will open a new market for digital radio receivers which can be designed and produced in South Africa. Once established, such electronic devices can also be exported to other markets within SADC, Africa and the world. South Africa as an innovation hub can even play an important role in the international rollout of DRM receivers serving markets such as India, Indonesia, Pakistan or Russia.

Job Creation and uplift of media industry

DRM will allow for the kick-off of digital radio without further delay as spectrum is already available. This means that jobs can be created immediately within the media industry which will also stimulate the sector, specifically within the community radio sector where numerous initiatives are lined up for consideration but cannot be helped yet due to lack of analogue spectrum.

Skills Development

The project will enable skills development in the very new field of digital radio. Through our community radio station we will encourage community members to participate on this pioneering project and divergent in the science and technology area of which the government has been encouraging and is in line with the governance policy in the science and technology sector. The newly empowered people from the community will in future be able to operate in other areas such as the Northern Cape where there is a specific demand for DRM+.

Demonstration of South Africa as an innovation base

The temporary license will empower Kofifi as an innovation hub. Thus in the Westbury area creating a snowball effect, South Africa will be recognised as pioneer conducting this first DRM+ trial on the African continent. In the Northern Cape, South Africa will be able to demonstrate that it has been

able to develop an answer to the special requirement on universal access to information versus spectrum usage restrictions in the Square Kilometre Array (SKA) area.

Better Signal Quality and additional programmes

Citizens will benefit from a better signal and audio quality and improve their access to information. Additional sound and multimedia services will open opportunities for new educational programmes, interactive services (e.g. employment service), weather and traffic information, emergency warning systems and many other benefits for the citizens and communities.

12. About WECODEC

The Westbury community of Johannesburg is a previously disadvantaged community that has endured a turbulent history. Due to the legacy of apartheid and the nature and constraints of both the previous and present political administrations, the community still suffers from a number of socio-economic ills. The main issues are high unemployment, poor housing, poor health, poverty, gang violence and drugs.

Within Westbury, a number of small self-help groups have risen to combat the effects of the social ills. A major catalyst force for change is the Westbury Community Development Centre (WECODEC). Spearheaded by a of young people – many of who were key role players in gang activities – the formation of WECODEC in 1998 became a turning point in the history of the Westbury and surrounding communities.

In the same year, WECODEC negotiated the first reconciliation between the rival gangs. This has resulted in a significant drop in violent crime. The team began to initiate self-sustaining projects designed to achieve the collective aims of poverty alleviation, skills development and social upliftment.

Today, the centre hosts a number of activities and resources including computer training, upgrading and maintenance, an internet-enabled resource centre, a library, a crèche, women's groups and prayer groups. WECODEC has become a beacon of inspiration for the community and now plays a critical role in representing the community both within and externally to all strata and society.

Through persistent effort, the team behind WECODEC has secured support and recognition from Government ministers, the private and NGO sector. Journalist and writer, Dr Don Mattera has been instrumental in the development of the project. As a leading figure in the struggle against apartheid, his personal commitment to the development of Westbury has inspired the hearts and minds of the community.

In pursuing its objectives WECODEC established a community radio station, **Kofifi FM 97.2**, in order to enhance its vision and purpose and is now broadcasting on air since 2012. The radio station is one of the few who are self-providing signal distribution via an SMME company due to its natural affinity to innovation and technology. Due to this interest, WECODEC recruited Mr Johannes von Weyssenhoff, an engineer and technical consultant from Germany on a skills transfer purpose who has then – inspired by WECODEC's work for the community – developed his passion for inventing and promoting technologies for community broadcasting including a solution for broadcasting community television in the L-Band. This solution was then worldwide firstly tested within the Westbury community and in early 2015 the idea was born to undertake WECODEC DRM trial in the FM Band (DRM+) to evaluate its benefits for community radio in South Africa.

13. Project Partners

WECODEC Partnerships and Enterprise Development

The successful launch of the community radio station has enabled WECODEC to establish and attract other strategic partners within and external to the community. The Kofifi Media Group of companies has been established out of this key strategic partnership which has then also enabled the radio station to grow exponentially. This symbiotic effect of the activities of a community radio station as NGO and enterprise development resulting in job creation and skills development within the community has been recognised as a ground-breaking community upliftment model. It has brought to life various business platforms, key strategic partnerships, and opportunities for the community.

The organization also renders community services such as feeding schemes, vegetable gardens and partnerships with local primary and senior secondary schools, as well as counselling. The collective organisations have established relationships with the local CPF's (Community Policing Forums) and with local and provincial government departments, as well as with MICT Seta for training and development of young entrants into the media industry, with a strong focus on youth and women with skills programmes, internships and learnerships currently being in place.

The organisation's IT and innovation hub has led to the development and ultimate partnership with the BBC, resulting in this technology trial to be initiated and brought to our country. Various sets of skills have been brought together through these partnerships i.e. engineering, entrepreneurial, financial, or construction etc.

About the BBC

Founded on 18th October 1922, The British Broadcasting Corporation is a British public service broadcasting statutory corporation. Its main responsibility is to provide impartial public service broadcasting in the United Kingdom, the Channel Islands, and the Isle of Man. Outside the UK, the

BBC World Service has provided services by direct broadcasting and re-transmission contracts on radio since the inauguration of the BBC Empire Service on 19 December 1932. More recently the BBC World Service has expanded its services to television and online.

About Fraunhofer IIS

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 67 institutes and research units at locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of 24,000, who work with an annual research budget totalling more than 2.1 billion euros.

The Fraunhofer Institute for Integrated Circuits IIS is one of the world's leading application-oriented research institutions for microelectronic and IT system solutions and services. It ranks first among all Fraunhofer Institutes in size. With the creation of mp3 and the co-development of AAC, Fraunhofer IIS has reached worldwide recognition.

In close cooperation with partners and clients the Institute provides research and development services in the following areas: Audio and Media Technologies, Imaging Systems, Energy Management, IC Design and Design Automation, Communication Systems, Positioning, Medical Technology, Sensor Systems, Safety and Security Technology, Supply Chain Management and Non-destructive Testing.

About Blulemon

BluLemon (Pty) Ltd was founded in 2005 by Mr. Russel Jones and has their head office in Edenvale, South Africa, has a level 4 BBBEE rating, and contributes towards social development programmes and skills development. The company is a wholly owned South African company that uses local expertise and local suppliers as well as it has extensive experience in international trade, both for import and export. Blulemon's equipment and services can be found all over the African continent, ranging from Nigeria to the Kenya and other Southern African countries.

BluLemon is a licensed Signal Distributor by ICASA. Besides Sentech and Orbicom, BluLemon is the only ECNS license holder who has already operated digital television transmitters in South Africa.

About CR Electronics

CR Electronics is a broadcast and solar energy equipment and service supplier located in Springs, South Africa. Founded by Eng. Carlos Rebelo in1989, the company is focused on green energy efficient technologies as well as broadcast transmitter and antenna installations and repairs. CR Electronics is a long term service partner of WECODEC/Kofifi FM97.2.

About Genssoft Technologies

Genssoft was formed in 2011 as ICT service provider with a key focus on eBusiness solutions, ICT strategy development, data recovery, support services, consulting and the implementation of technology that caters for both private and public enterprises large or small holistically. The company's philosophy of incorporating employees, associates and partners as shareholders has augured well for the establishment of a solid framework of committed individuals that deliver cost-

effective solutions. From inception, Genssoft has had a dedicated social responsibility programme. The organization's skills set and ownership is previously disadvantaged individuals (PDI's) and global stakeholders which assist in development and share transfer of knowledge across the broader build on international standards.

14. Acknowledgements

This project has been possible by a concerted teamwork of many enthusiastic believers in this technology and its relevance and benefits specifically to marginalized communities in South Africa and Africa. In this section we would like to express our acknowledgement to individuals and organizations that have contributed to make this wonderful project happen.

Special thanks to:

The people and leaders of the Westbury Community – special thanks to Pastor Peter Faver, Joseph Cotty, and Azziz Kara (project sponsors);

The WECODEC project team – special thanks to Johannes von Weyssenhoff (engineering and technology), Thembeka Khaka (strategy; regulatory and compliance; policy), Lee Tsomo (Project Management), as well as Clinton Adams and David Boer (field technicians); Devendra Karedla (IT)

Khomotso Motsepe, Emeka D. Okawkwu, and their team at ICASA for their interest in innovation and cooperation during the preparation and operation of the trial;

Mothibi Ramusi for strategic advice and mentoring with compliance matters;

BBC for contributing the broadcast equipment;

Fraunhofer Institute for Integrated Circuits for contributing Multimediaplayer software and Journaline support – special thanks to Alex Zink, Thomas Dettbarn, Guido Leisker and Martin Speitel;

The DRM Consortium Project Office and members for their assistance in initiating this trial and hosting WECODEC at IFA and IBC – special thanks to Ruxandra Obreja, Olaf Korte and Matthias Stoll;

Carlos Rebelo for helping with RF installations;

Ryan Miller of SoundWaves for contributing a car radio antenna and preparing our vehicle;

GlobeCast for contributing additional equipment;

Russel Jones for contributing Electronic Communications Network Services.

15. Glossary

A/D	Analogue-to-Digital
AGC	Automatic Gain Control
AM	Amplitude Modulation
BBC	British Broadcasting Service

BDM	Broadcast Digital Migration
CEPT	European Conference of Postal and Telecommunications Administrations
CF	Correction Factor
COFDM	Coded Orthogonal Frequency Division Multiplexing
CRASA	Communications Regulators Association of Southern Africa
CTB	Communications Technology Broadcasting
DAB+	Digital Audio Broadcasting
D.F.	Dipole Factor
dB	Decibel
dBµV/m	dB-microvolt per meter
Δf (delta-f)	Frequency spacing
ΔP (delta-P)	Power difference
DoC	Department of Communications
DRM	Digital Radio Mondiale
DRM30	Digital Radio Mondiale for broadcast frequencies below 30MHz
DRM+	Digital Radio Mondiale for broadcast frequencies above 30MHz
DTPS	Department of Telecommunications and Postal Services
EBU	European Broadcasting Union
ECA	Electronic Communications Act of South Africa
ECC	Electronic Communications Committee within CEPT
EEP	Equal Error Protection
EPG	Electronic Program Guide
ERC	European Radiocommunications Committee
ERP	Effective Radiated Power
ETSI	European Telecommunications Standards Institute
FAC	Fast Access Channel
FM	Frequency Modulation

FS	Field Strength
HASL	Height Above Sea Level
HE-AAC	High Efficiency Advanced Audio Codec
IBC	International Broadcast Convention (in Amsterdam, The Netherlands)
ICASA	Independent Communications Authority of South Africa
ICT	Information and Communication Technology
ISO	International Standard for Standardization
ITU	International Telecommunications Union
kHz	Kilo Hertz
kW	Kilo-Watt
L-Band	Frequency Band 1.452-1.492 GHz
MER	Modulation Error Ratio
MF	Medium Frequency
MOT	Multimedia Object Transfer (Picture Slideshow format in DAB/DRM)
µV	mikro-Volt
MHz	Mega Hertz
MPEG	Motion Picture Engineering Group
MSC	Main Service Channel
MW	Medium Wave
QAM	Quadrature Amplitude Modulation
RCSI	Receiver Status and Control Interface
RF	Radio Frequency
RSG	Radio Sonder Grense
RTL-SDR	Realtek 2832U based software defined radio
SABC	South African Broadcasting Corporation
SABS	South African Bureau of Standards
SADIBA	South African Digital Broadcasting Association

SDC	Service Description Channel
SDR	Software Defined Radio
SFN	Single Frequency Network
SKA	Square Kilometre Array (located in the Northern Cape, South Africa)
S/N	Signal-to-Noise Ratio
SW	Short Wave
TPEG	Transport Protocol Experts Group (a data protocol suite for traffic and travel related information used in digital broadcasting)
UHF	Ultra-High Frequency
UHF Band	Frequency Band 470-870MHz
V/m	Volts per meter
VHF	Very High Frequency
VHF Band I	Frequency Band 47-68MHz
VHF Band II	Frequency Band 87.5-108MHz (same as FM Band)
VHF Band III	Frequency Band 174-254MHz (in South Africa)
VSWR	Voltage Standing Wave Ratio
xHE-AAC	Extended High Efficiency Advanced Audio Codec

Authorized: _____ _____

Pastor Peter Faver Place, Date